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TITLE: **NEUTRONIC DESIGN CONSIDERATIONS FOR ACCELERATOR TRANSMUTATION OF LWR WASTE**

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NEUTRONIC DESIGN CONSIDERATIONS FOR ACCELERATOR TRANSMUTATION OF LWR WASTE

by

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We are designing a system that uses a high neutron flux produced by a beam of accelerated protons to transmute large quantities of both actinide and fission product wastes from light water reactors. Fissions induced in the actinide multiply the source, but the system remains subcritical. Earlier designs[1,2] showed the feasibility of processing wastes from the depositories at the DOE facility at Hanford, WA within 30 years using a blanket containing aqueous slurries. Those design goals were rapid transmutation of fission products and relatively slow actinide burns (with $k_{eff} \leq 0.70$) consistent with smaller actinide waste inventories at Hanford. Present studies focus on processing fission products in the presence of high level wastes from LWR's at $k_{eff} \leq 0.95$. Neutronic calculations are performed with one- and two-dimensional S_n codes.

Figure 1 shows a radial schematic of the target-blanket configuration. The target consists of solid cylindrical tungsten plates spaced at intervals along the axis to reduce neutron loss in the target. The tungsten is surrounded by a region of solid lead and D_2O. Both target regions are homogenized in one-dimensional modeling. The Pb is followed by an aluminum target structure, a Zircaloy tank wall, a thin 1-molar Tc-D_2O buffer region of variable thickness, and the active actinide blanket region surrounded by a D_2O outer reflector.

The actinide is contained at high pressure in 250 tubes in a hexagonal lattice. We assume a calculated[3] equilibrium actinide composition attained during irradiation of LWR wastes in a flux of 1.0×10^{15} n/cm^2-sec. We analyzed an individual lattice cell of infinite length to maximize its k_{eff} (i.e., k_∞ in the non-leaking unit cell). Each cell contains the actinide slurry within Zr-Nb tubes (double-walled with a total thickness of 1.23 cm) surrounded by a zone of D_2O moderator.

Initial unit cell calculations investigated the effects of actinide concentration, tube size, and tube spacing on k_∞, with the following results: (1) As actinide concentration increases from 5 g/l, k_∞ sharply increases at first, but above 30 g/l it begins to level off and eventually to decline, due to a hardened fission spectrum and enhanced resonance captures in the nonfissile isotopes. (2)

Increasing the (inner) tube radius from small values (1 cm) has a positive, but small, effect on k_∞. (3) The pitch must provide several cm of D_2O between outer tube walls for effective moderation. (The full blanket size depends linearly on the pitch.) Based on these results, we selected an actinide concentration of 75 g/l, an inner tube radius of 5.0 cm, and a 23.8-cm pitch, and this gave k_∞=1.158.

We then simulated absorption in the unit cell due to calculated buildup[3] of fission products (excluding Tc and I), during a 10-day exposure to a flux of 1.0×10^{15} n/cm²-sec; this was done by incorporating an amount of ^{10}B into the slurry that resulted in the equilibrium fission-product:actinide absorption ratio. This reduced k_∞ for the unit cell by 0.057.

In our full blanket calculations we homogenized the unit cell to maintain cylindrical symmetry; constituent materials and cross sections were flux-volume weighted to preserve reaction rates. Radial leakage and neutron capture in blanket materials reduced k_{eff} by another 0.057, and an additional 0.035 was lost in the inclusion of an axial-leakage approximation into the one-dimensional calculation. The resulting blanket k_{eff} was 1.009.

In the remaining calculations we simulated the burning of long-lived fission products. Tc entered the blanket in two independent locations: (1) the variable buffer zone (at 1 molar concentration) and (2) homogeneously throughout the actinide region and the outer reflector. The absorbing Tc reduced k_{eff} from the initial value of 1.009 to selected fixed values.

Results showed that, generally, more waste material can be processed when operating at a higher k_{eff}, and that, at fixed k_{eff}, one can adjust the Tc buffer width to enhance either the Tc transmutation or the actinide fission at the expense of the other. For a 140-mA beam of 800 MeV protons, a blanket with k_{eff}=0.95 and a buffer thickness of 1.9 cm will operate at a power level of 1542 MW and transmute the actinide and fission-product wastes from 1.88 PWR's.

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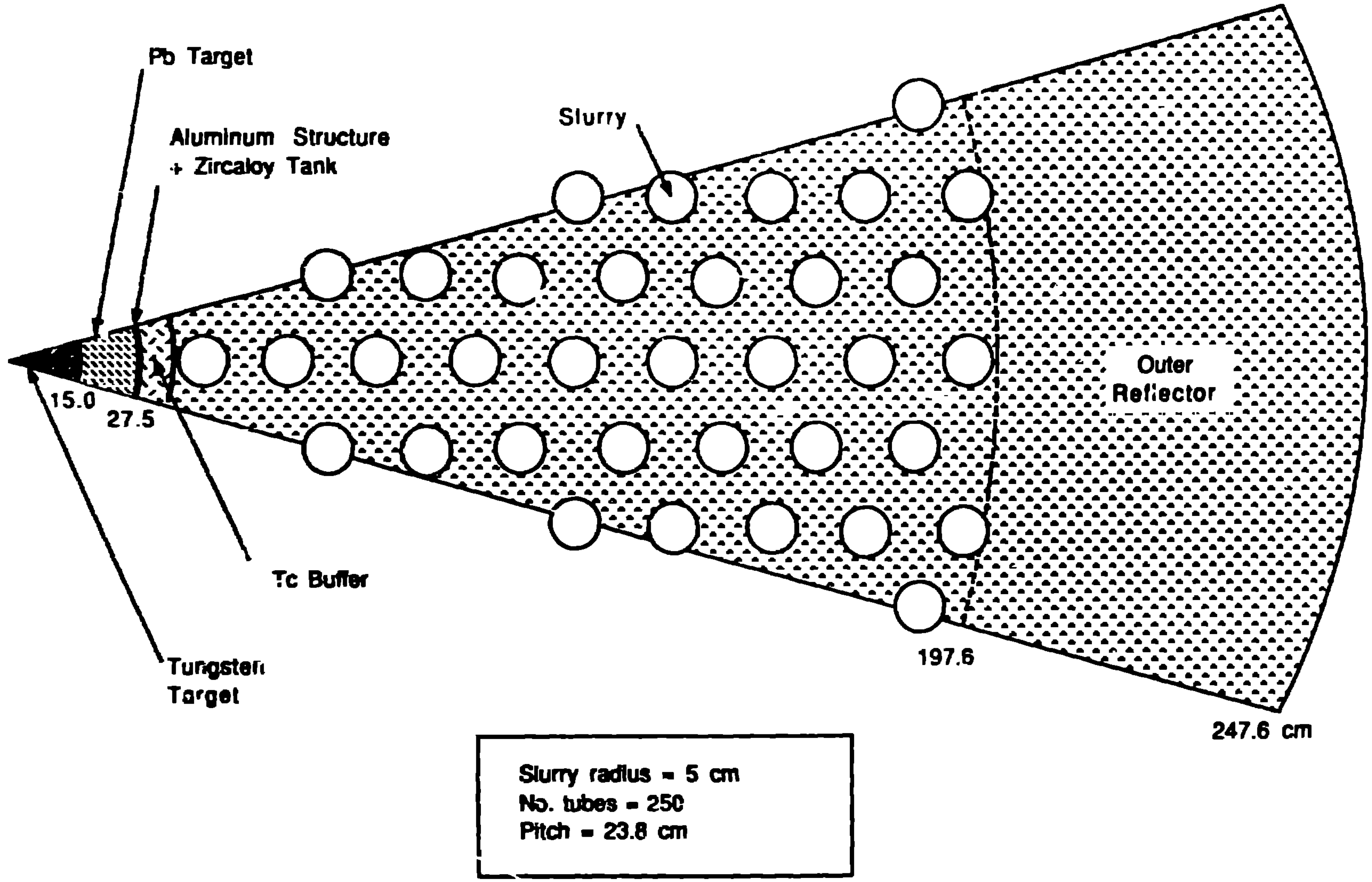

Fig. 1. Schematic of aqueous ATW target-blanket configuration.